

Development of a robust, high current, low power field emission electron gun for a spaceflight reflectron time-of-flight mass spectrometer

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Carbon materials, including carbon nanotubes (CNTs) and nitrogen-incorporated ultrananocrystalline diamond (N-UNCD), have been of considerable interest for field emission applications for over a decade. In particular, robust field emission materials are compelling for space applications due to the low power consumption and potential for miniaturization. A reflectron time-of-flight mass spectrometer (TOF-MS) under development for *in situ* measurements on the Moon and other Solar System bodies uses a field emitter to generate ions from gaseous samples, using electron ionization. For these unusual environments, robustness, reliability, and long life are of paramount importance, and to this end, we have explored the field emission properties and lifetime of carbon nanotubes and nitrogen-incorporated ultrananocrystalline diamond (N-UNCD) thin films, the latter developed and patented by Argonne National Laboratory. We will present recent investigations of N-UNCD as a robust field emitter, revealing that this material offers stable performance in high vacuum for up to 1000 hours with threshold voltage for emission of about 3-4 V/ μm and current densities in the range of tens of μA . Optimizing the mass resolution and sensitivity of such a mass spectrometer has also been enabled by a parallel effort to scale up a CNT emitter to an array measuring 2 mm x 40 mm. Through simulation and experiment of the new extended format emitter, we have determined that focusing the electron beam is limited due to the angular spread of the emitted electrons. This dispersion effect can be reduced through modification of the electron gun geometry, but this reduces the current reaching the ionization region. By increasing the transmission efficiency of the electron beam to the anode, we have increased the anode current by two orders of magnitude to realize a corresponding enhancement in instrument sensitivity, at a moderate cost to mass resolution. We will report recent experimental and modeling results to describe the performance of a field emission electron gun as employed in the Volatile Analysis by Pyrolysis of Regolith (VAPoR) TOF-MS prototype.

Keywords: Electron gun, field emission, carbon nanotubes, ultrananocrystalline diamond, time-of-flight mass spectrometer

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